Load Dynamics of a Multiplayer Online Battle Arena and Simulative Assessment of Edge Server Placements

Valentin Burger, Jane Frances Pajo, Odnan Ref Sanchez, Michael Seufert, Christian Schwartz, Florian Wamser, Franco Davoli, Phuoc Tran-Gia

www3.informatik.uni-wuerzburg.de
Competitive Online Gaming

Load Dynamics of a Multiplayer Online Battle Arena

Valentin Burger
League of Legends and Dota 2 together have more than 80 million unique players every month.

Dota 2 makes $18 million each month, League of Legends makes the same amount each 5 days.

The price pool of the international Dota 2 championship 2015 was $18,429,613.

In 2015 Twitch.tv had 421.6 monthly minutes watched per viewer compared to 291.0 monthly minutes watched per YouTube viewer.
Multiplayer Online Battle Arena

- Two teams of 5 players compete on map to destroy enemy base
- Team work and strategy are key to winning
- High importance of fast reaction times and corresponding network requirements
Pushing Intelligence to the Edge

- Latency considerably influences the game play and the users’ gaming experience

- Huge amount of concurrent players puts high load on network resources

- Migrate game server virtual machines to edge nodes and push intelligence to the edge of the network

- Save network resources in the core network
- Reduce latency of players and improve quality of gaming experience

- Where to allocate how much capacity for edge nodes and when?
- What is the potential to reduce latency and network resources?
Simulation Model

- Set of server resources (DS) with capacity $C_{DS}$
- Set of edge resources (ES) with capacity $C_{ES}$
- Links connecting server resources and edge resources with capacity $\rho$
- Party and single player arrival rates $\lambda_P/\lambda_S$
- Location $\xi_i$ of request $i$
Model Requirements

_location of game servers

arrival rate of game requests

player locations

duration of matches
Data Collection

- Dota 2 match histories derived from API calls
  - Game start time and date
  - Game duration
  - Server location (region)
- Measurement period was from March 18\textsuperscript{th} to March 25\textsuperscript{th}, 2015
- More than 1 million games per day
- 8,470,933 public Dota 2 matches and 1,786,148 unique public player profiles crawled in total
Dota 2 Regions and Server Locations

- **US West** Seattle, WA, USA
- **US East** Sterling, VA, USA
- **Europe West** Luxembourg
- **Europe East** Vienna, Austria
- **SE Asia** Singapore
- **China** Shanghai
- **South America** São Paulo, Brazil
- **Russia** Stockholm, Sweden
- **Australia** Sydney, Australia
Daily Dynamics of Game Requests

- Arrival rate of matches $\lambda$ dependent on time and region
- Time shift and different load / peak load per region
Game Request Arrival Process

- Approximate empirical distribution of inter-arrival time of requests with exponential distribution $f(x, \beta) = \frac{1}{\beta} \exp(-\frac{x}{\beta})$
- Mean inter-arrival time $\beta$ is set according to hourly arrival rate $\lambda$

Non busy hour (4:00 AM) $\beta = 3.6$

Busy hour (6:00 PM) $\beta = 1.8$
Weekly Dynamics of EU West Server

- Decomposition by Fourier analysis (DFT)
- Approximation by the five most significant Fourier terms (sines)
  - Daily periodic pattern
  - Transition of decreasing rates from the weekdays to the week-end
Player Location

- Determine player counts per country from public Steam profiles to estimate the country probabilities
- 757,172 public-profiled accounts with a unique player ID in total that had set their locations
- 324,511 of these played on the EU West server

<table>
<thead>
<tr>
<th>Rank</th>
<th>Country</th>
<th>Players</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Russia</td>
<td>115210</td>
<td>0.355</td>
</tr>
<tr>
<td>2</td>
<td>Ukraine</td>
<td>39605</td>
<td>0.122</td>
</tr>
<tr>
<td>3</td>
<td>Great Britain</td>
<td>15078</td>
<td>0.046</td>
</tr>
<tr>
<td>4</td>
<td>Germany</td>
<td>12565</td>
<td>0.039</td>
</tr>
<tr>
<td>5</td>
<td>Belarus</td>
<td>12322</td>
<td>0.038</td>
</tr>
</tbody>
</table>
Player Distribution on Cities

- Empirical probability $f_x$ of a player being in country $x$ is determined by player count per country.
- Given country $x$ the probability $f_y$ of a player playing in city $y$ is determined by the population distribution $f^{y}_x$ of cities in country $x$.

- Player locations $\xi_i$ are generated according to two schemes:
  - **Random**: Single player looks for other random players (solo queuing)
    - City $y$ is determined according to $f^{y}$.
    - Exponentially distributed distance with parameter $d_{\text{rnd}}$ added in a uniformly distributed angle to coordinates of center of city $y$.
  - **Party**: Friends playing together (party queuing)
    - Relies on assumption that probability of friendship decreases exponentially with distance.
    - Determine location of first player according to random scheme.
    - Exponentially distributed distance of remaining $k-1$ players from first player with parameter $d_{\text{party}}$. 
Match Durations on EU West Server

- 1,368,703 regular matches played from March 18th to March 25th
- Average match duration of 2590 seconds (ca. 43 minutes), standard deviation of 685 seconds
- Match duration modeled with log-normal distribution
Simulation Description

- Simulation implemented in Java using the JSimLib (DES) library
- ESs are distributed by ranking the cities according to $f^y$
- Migration Policy
  - Servers are sorted by increasing mean distance of the players
  - Match is hosted on first server with enough capacity in the list

*10 players per match

match dropped

GameStart

Migrate

deferred_q

MatchEnd
## Parameters and Metrics

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Default</th>
</tr>
</thead>
<tbody>
<tr>
<td>$C_{DS}$</td>
<td>Dedicated server capacity</td>
<td>3000</td>
</tr>
<tr>
<td>$n_{ES}$</td>
<td>Number of edge servers</td>
<td>0</td>
</tr>
<tr>
<td>$C_{ES}$</td>
<td>Edge server capacity</td>
<td>1000</td>
</tr>
<tr>
<td>$\lambda$</td>
<td>Arrival rate of requests</td>
<td></td>
</tr>
<tr>
<td>$k$</td>
<td>Number of players per match</td>
<td>10</td>
</tr>
<tr>
<td>$\mu$</td>
<td>Match service rate</td>
<td></td>
</tr>
<tr>
<td>$\rho$</td>
<td>Throughput of edge link</td>
<td></td>
</tr>
<tr>
<td>$\sigma$</td>
<td>Memory footprint</td>
<td></td>
</tr>
<tr>
<td>$d_{rd}$</td>
<td>Distance from city center</td>
<td>5 km</td>
</tr>
<tr>
<td>$d_{party}$</td>
<td>Distance from party leader</td>
<td>100 km</td>
</tr>
</tbody>
</table>

### Performance Metrics
- Load on dedicated server: number of matches
- Game play experience: mean distance to server
Daily dynamics of server load
Load on server decreases with the number of edge servers
Deploying 1 ES with decent capacity already reduces the peak load on the DS by around 75%
Mean distance decreases with the number of edge servers
Saturation effect for random players due to distance among them
Resources Allocation Schemes

- Investigate effect of resource allocation schemes on performance metrics

- Fix total capacity of edge servers to $C_{ES, tot} = \{128, 256, 512\}$ matches

- Compare uniform and non-uniform resource allocation
  - Uniform (u):
    $C_{ES, tot}$ is equally shared among the ESs
  - Non-uniform (nu):
    $C_{ES, tot}$ is allocated according to population in the ES locations
- High number of edge servers with smaller capacities is beneficial.
- Non-uniform placement performs worse in cases where optimal location has no capacity (left).
Multiplayer online battle arenas are rising online gaming services

Performance of player and gaming service highly depend on the distance and latency to the game server

We developed generic stochastic models for the load dynamics of the multiplayer online battle arena Dota 2 by evaluating match histories from the provided API

The models are used to evaluate mechanisms aiming to improve the performance of the gaming service by pushing servers to the edge of the network

Part of future work is to determine optimal resource allocations